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Original article

Dynamic component of sports is an important determinant factor of heart rate recovery

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KEYWORDS
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Summary
Objective: It is usually suggested that life expectancy of top athletes especially in endurance sports is longer than that of sedentary people. On the other hand, heart rate recovery (HRR) after exercise is an independent risk factor for cardiovascular disease and mortality, but differences in HRR between various top athletes are unclear. We examined HRR in various top athletes to clarify a role of HRR that may affect their life expectancy.
Methods: HRR was defined as the difference between the heart rate at peak exercise and that at 2 min after the finish of exercise using symptom-limited maximal graded bicycle ergometer exercise testing. The relationships between HRR with the grade of static and dynamic component of classification of sports, age, and body mass index (BMI) were estimated.
Subjects: The subjects were 720 male athletes participating in the National Sports Festival Japan in 2005—2008 and age-matched 28 sedentary controls.
Results: HRR was significantly correlated ($p < 0.0001$) with the higher grade of dynamic component of sports, younger age, and lower BMI in both univariate and multivariate analysis.
Conclusions: HRR of top athletes is predicted by increased dynamic component of sports, younger age, and lower BMI.

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Introduction

It is usually suggested that life expectancy of top athletes especially in endurance sports is longer than that of sedentary people [1—3]. On the other hand, the extent of heart rate recovery (HRR) after exercise has been shown to be an independent risk factor for cardiovascular disease and mortality in healthy adults [4—6]. However, differences in HRR of elite athletes among various sports categories are unclear. The purpose of the present study was to examine the differences in HRR of elite athletes with various sports categories and elucidate the determining factors of HRR.

Subjects

The subjects were 720 male athletes participating in the National Sports Festival Japan in 2005—2008 aged 14—40 years (mean age: 20.1 ± 5.6 years). Additionally, 28 age-matched male sedentary controls (mean age: 20.7 ± 5.4 years) were estimated. The athletes included 13 archers, 50 ice hockey players, 8 weight lifters, 14 canoeists, 30 field hockey players, 7 rifle shooters, 4 golfers, 60 soccer footballers, 3 synchronized swimmers, 5 downhill skiers, 4 cross-country skiers, 9 sailors, 30 softball players, 21 tennis players, 53 basketball players, 18 badminton players, 44 volley ball players, 65 handball players, 24 figure skaters, 8 fencers, 5 bowlers, 36 rowers, 2 boxers, 14 rugby footballers, 9 martial artists, 14 cyclists, 10 judoists, 23 swimmers, 8 sumo wrestlers, 28 gymnasts, 4 table tennis players, 37 long distance runners, 4 equestrians and 47 baseball players. Written informed consent for this study was obtained from all subjects. Approval of the study was also obtained from the Research Ethics Committee of Yokohama City Sports Medical Center.

Methods

Classification of sports

All athletes were classified according to the classification of sports of 36th Bethesda Conference report [7]. In that classification, each sport is categorized by the level of intensity (low, medium, and high) of dynamic and static exercise generally required to perform that sport during competition. The increasing dynamic component is defined in terms of the estimated percent of maximal oxygen uptake (VO_2max) achieved and categorized as A = Low (<40% VO_2max), B = Moderate (40—70% VO_2max), and C = High (>70% VO_2max). The increasing static component is related to the estimated percent of maximal voluntary contraction (MVC) reached and categorized as I = Low (<20% MVC), II = Moderate (20—50% MVC), and III = High (>50% MVC). Consequently, that classification consisted of 9 categories of sports. In the concrete, IA (rifle shooters, bowlers, and golfers), IB (softball players, volley ball players, fencers, and baseball players), IC (field hockey players, soccer footballers, tennis players, badminton players and long distance runners), IIA (archers and equestrians), IIB (synchronized swimmers, figure skaters, rugby footballers, and swimmers), IIC (ice hockey players, cross-country skiers, basketball players, and handball players), IIIA (weight lifters, sailors, martial artists, sumo wrestlers, and gymnasts), IIIB (downhill skiers and judoists), and IIIC (canoeists, rowers, boxers, and cyclists) were classified.

Examination

The body mass index (BMI) was calculated as body weight (kg)/height (m)^2. Symptom-limited maximal graded exercise testing was done on an electronic bicycle ergometer (The Multi Exercise Test System, ML-1800, Fukuda-Denshi, Tokyo, Japan) using a ramp protocol [8]. The exercise test was stopped if the subject became too fatigued and could not continue pedaling. Following peak exercise, the subjects cooled down for 1.5 min at 60 revolutions per minute (1 min with a 20 W load and 30 s without a load). The electrocardiogram was recorded automatically every minute before, during, and after exercise test. HRR was defined as the difference between the heart rate at peak exercise and that at 2 min after the finish of exercise [9].

Statistical analysis

The values are expressed as the means ± SD. The HRR in each sports category was compared by one-way analysis of variance with repeated measures and Fisher's protected least significant difference test. Correlations of HRR with age and BMI were examined by Spearman's correlation analysis. HRR data for subjects performing static (sedentary, I, II, and III) and dynamic (sedentary, A, B, and C) sports were examined by Pearson's correlation analysis. Multiple regression analysis was done by using the age, BMI, static sports (sedentary = 0, I = 1, II = 2, and III = 3) and dynamic sports (sedentary = 0, A = 1, B = 2, and C = 3) as dependent variables versus HRR as the independent variable. A probability value <0.05 was considered significant.

Statistical analysis was done with a Hitachi FRORA 310W computer (Hitachi Electronics Co., Tokyo, Japan), using the Stat View 5.0 program (SAS Institute, Inc., Cary, NC, USA).

Results

HRR of the athletes and sedentary controls is shown in Fig. 1 (in alphabetical order). Mean age and BMI of the subjects (in each sporting category) are shown in Figs. 2 and 3. The peak HR and % maximal predicted HR for age of subjects in each sporting category are shown in Figs. 4 and 5. There was no relationship between HRR and the peak HR or % maximal predicted HR for age in athletes, but there was in the sedentary controls (Fig. 6). HRR in sedentary controls was smaller than athletes except for subjects in class IIA (Fig. 7). In athletes with low static component of sports, HRR in class IC was significantly larger than those of class IA (p = 0.0394) and class IB (p < 0.0001). In athletes with moderate static component of sports, HRR in class IIB and class IIC was significantly larger than those of class IIA (p = 0.0024 and p = 0.0002). In athletes with high static component of sports, HRR in class IIIC was significantly larger than those of class IIIA (p = 0.0053) (Fig. 7). In univariate analysis, HRR was significantly correlated (p < 0.0001) with higher grade of dynamic classification

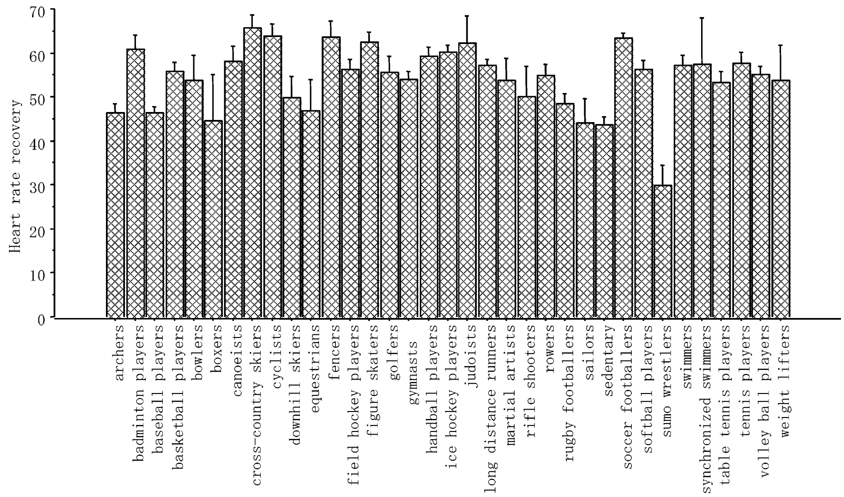

Figure 1 Heart rate recovery in various athletes and sedentary control.

of sports, younger age, and smaller BMI, but not correlated with static classification of sports (Fig. 8). According to multivariate analysis, HRR was significantly correlated ($p < 0.0001$) with higher grade of dynamic classification of sports, younger age, and smaller BMI (Table 1).

Discussion

It is well known that HRR is related to VO_2max, but as far as we know, there have been no previous reports on differences of HRR among elite athletes from different sporting categories. The present study showed that HRR in athletes

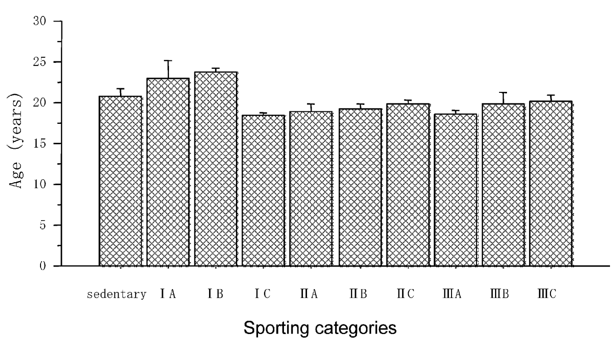

Figure 2 Mean age in athletes with classification of sports and sedentary controls.

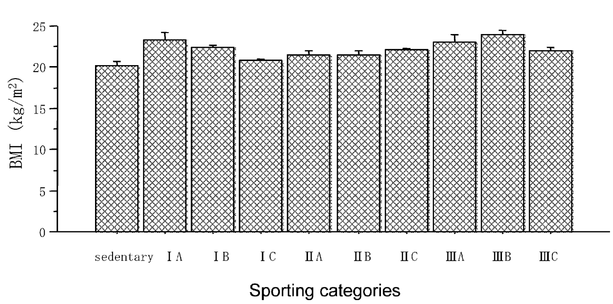

Figure 3 Mean body mass index (BMI) in athletes with classification of sports and sedentary controls.

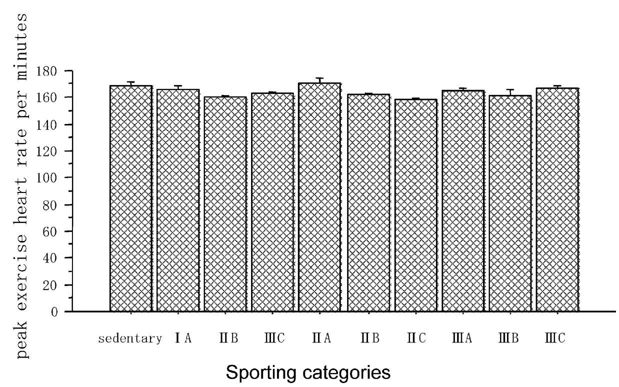

Figure 4 The peak exercise heart rate in athletes with classification of sports and sedentary controls.

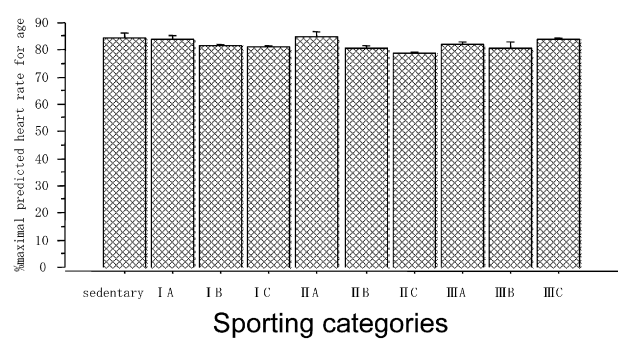

Figure 5 % Maximal predicted heart rate for age in athletes with classification of sports and sedentary controls.

Table 1 Predictors of heart rate recovery ($n = 720$).

	β	p
Component of static sports	0.228	0.8197
Component of dynamic sports	6.956	<0.0001
Age (years)	−8.191	<0.0001
Body mass index (kg/m^2)	−5.433	<0.0001

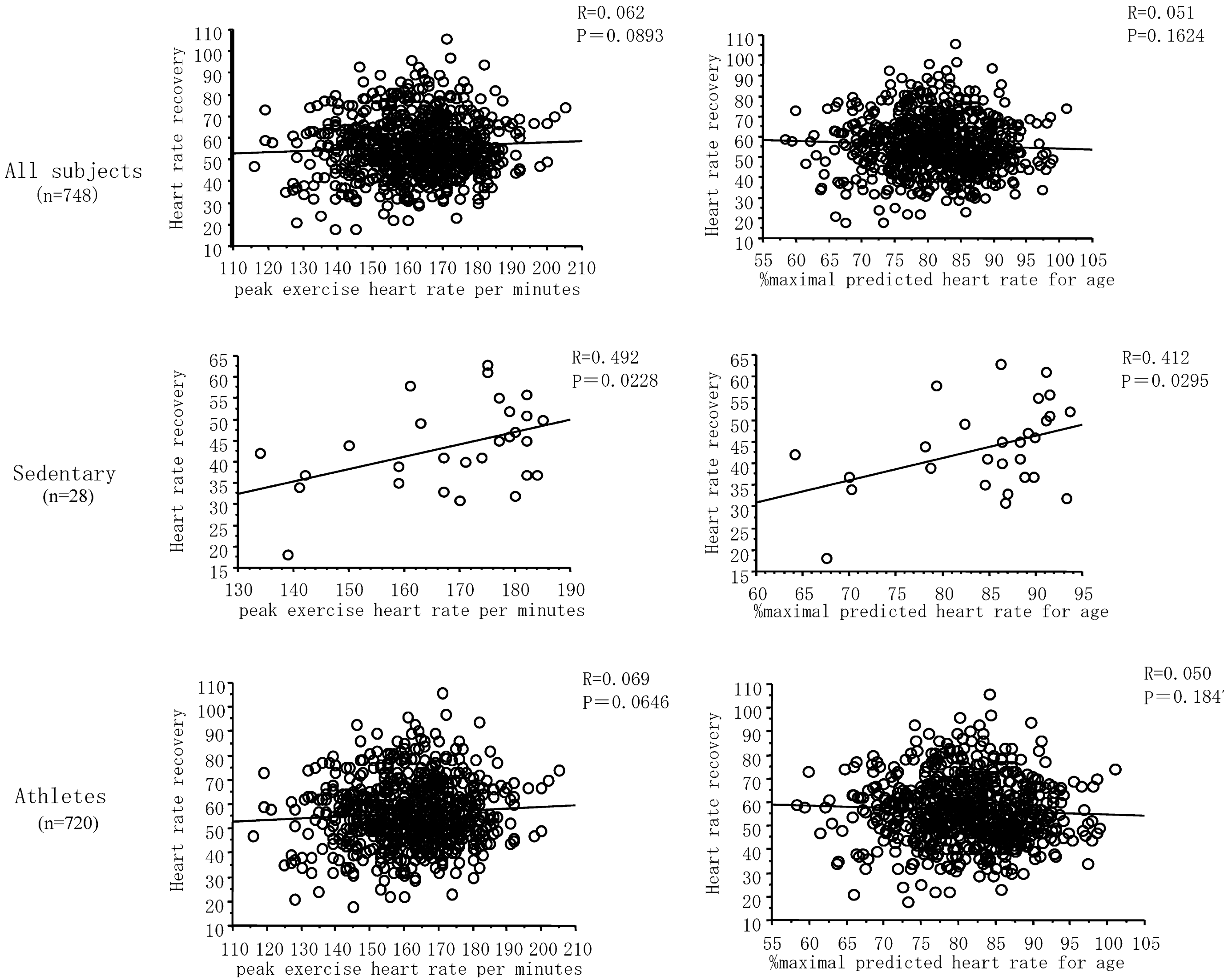

Figure 6 Relationship between heart rate recovery and the peak heart rate or % maximal predicted heart rate for age.

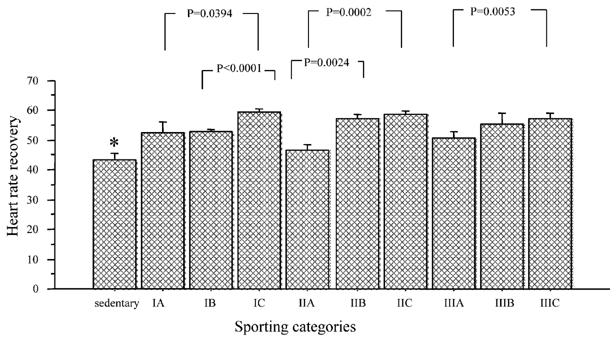

Figure 7 Heart rate recovery in athletes with classification of sports and sedentary controls.

participating in highly dynamic component of sports (class C) was greater than that of low dynamic component of sports (class A) in all grades of static component of classification of sports (classes I, II, and III). Additionally, HRR in class IC was greater than class IB and HRR in class IIB was greater than class IIA. There was a tendency that a higher level of dynamic component of sports predicted larger HRR. Furthermore, younger age and lower BMI are independent predictors of larger HRR. It is widely accepted that the improvement in HRR caused by improved cardiopulmonary fitness is due to increased vagal tone along with an increase of VO_2max [10]. Furthermore, previous studies have shown that physical training not only improves HRR in ordinary people but also in athletes [11]. On the other hand, several studies have demonstrated that weight loss increases vagal tone in obese people [12,13]. And we also showed that an exercise and weight loss program improves HRR in Japanese obese people [9]. In the present study, there was no relationship between the peak HR or % maximal predicted HR for age and HRR in athletes, but there was in sedentary controls. Recently, Zaim et al. reported a relation between the peak HR attained during exercise and the subsequent HRR in 164 patients who were referred for a symptom-limited standard Bruce Protocol treadmill exercise test, based on clinical indications [14]. Furthermore, our previous study showed the same relationship in 125 obese persons [9]. The reason that athletes in the present study showed no relation between the peak HR or % maximal predicted HR for age and HRR could be related to differences in performing the exercise test. All of our subjects stopped the exercise test because of leg fatigue resulting in stopped pedaling before they developed shortness of breath. Thus, many athletes may not have reached their maximum cardio-pulmonary capacity and different results may have been obtained if we had performed a treadmill exercise test. Although the mechanisms underlying HRR are not completely understood, several studies have suggested that HRR is probably influenced by changes in vagal activity [15,10,16]. Regarding the relationship between age and HRR, several studies showed a linear correlation between age and HRR, however, HRR is modifiable by physical fitness that affects cardiopulmonary functions (i.e. VO_2max) [17,18].

Sarna et al. studied life expectancy of 2613 Finnish male world class athletes [1]. They concluded that life expectancy

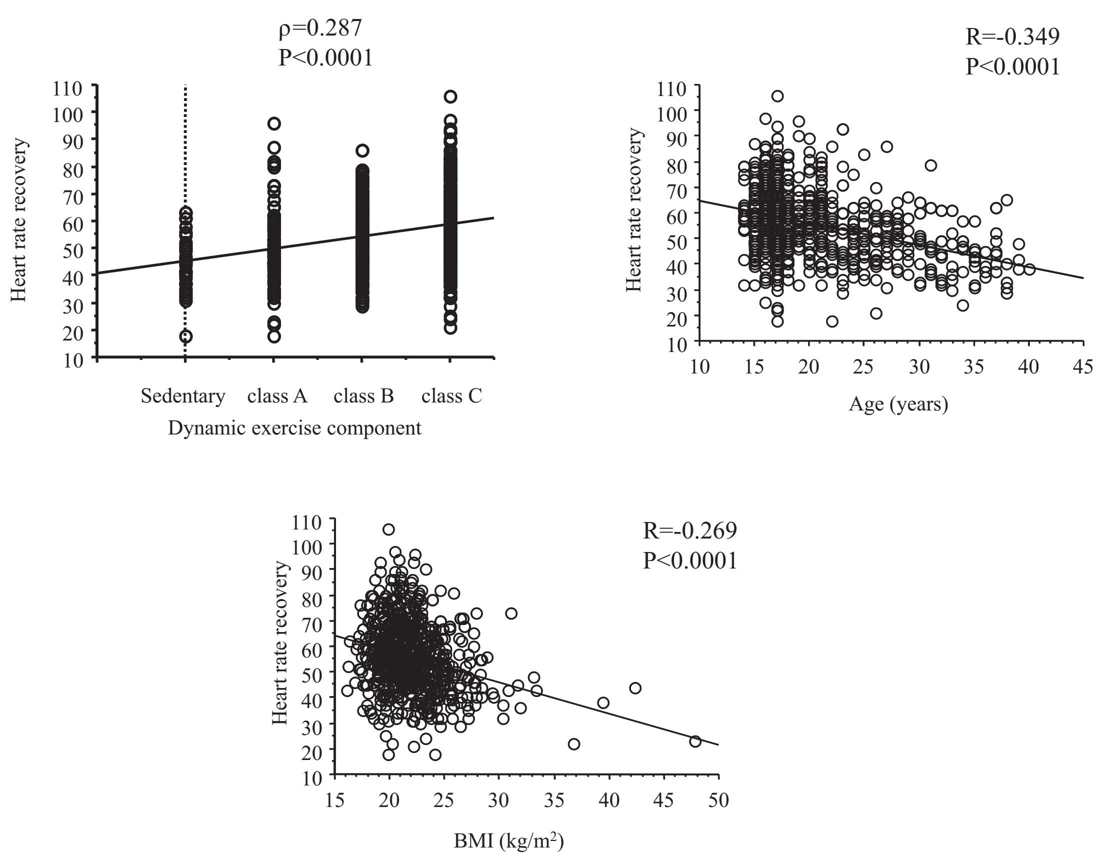

Figure 8 Correlations between heart rate recovery and the grade of classification of sports, age, and body mass index (BMI).

of participants of dynamic sports was longer than that of participants of static sports and sedentary people. Additionally, they showed increased mean life expectancies were mainly explained by decreased cardio-vascular mortality due to their sustained higher level of leisure time physical activity after competitive period. However, they did not show that power athletes did not have an increased life expectancy. In Japan, there are no reports about life expectancy of world class athletes, so we do not have the data about the differences in life expectancy of categories of sports. If, like Finnish athletes, Japanese athletes sustain higher level of leisure time physical activity after the competitive period, the same result may be given in the future about life expectancy and category of sports. For the moment, our result that higher dynamic component of participative sports predicts larger HRR may explain in part the mechanisms of longer life expectancy of dynamic athletes than static athletes and sedentary people. However, this is only speculation because we have no data about the prognosis of our subjects. Accordingly, we should follow up their life expectancy to verify our speculation.

Study limitations

The first limitation is that our study was performed with ergometer testing, while several other studies used treadmill testing to determine HRR. This difference in exercise methods may have affected the results obtained.

The second limitation is dispersion of number of athletes to participating sports. In the future, we should reinvestigate more large subjects enough in each item of sport.

The third limitation is that we used BMI for estimation of physique of athlete. Several studies used lean body mass to estimate physique of athletes. The difference of BMI and lean body mass may affect the result.

The fourth limitation is that we used classification of sports of 36th Bethesda conference report that is made for eligibility recommendations for competitive athletes with cardiovascular abnormalities. A different result might be obtained if we categorize using examination of VO_2max and MVC for each subject.

Conclusions

Large HRR of top athletes is predicted by increased dynamic component of sports, younger age, and lower BMI.

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